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DIGESTIBILITY OF PROTEIN SUPPLIED BY SOY-BEAN AND PEANUT PRESS-CAKE FLOURS.[1]

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CONTENTS.

	Page.
Introduction	1
Investigations of digestibility of common legumes	2
Source and available supply of soy-bean and peanut press cakes	3
Factors considered in determining food value of a protein	4
The amino acids supplied by soy-bean and peanut proteins as compared with those supplied by common cereal proteins	5
Biologic value of soy-bean and peanut proteins as compared with that of common cereal proteins	8
Digestibility of soy-bean and peanut proteins	12
Preparation of soy-bean and peanut press-cake flours	12
The subjects of the digestion experiments	14
Preparation of experimental diets	14
Details of the experiments	15
The digestibility of protein supplied by soy-bean press-cake flour	16
The digestibility of protein supplied by peanut press-cake flour	19
Experiments with flour made from roasted peanuts	20
Experiments with flour made from raw peanuts	22
Summary of all experiments with peanut flours	23
General conclusions regarding the value of soy bean and peanut flours as food	25

INTRODUCTION.

It has long been recognized that in order to maintain the well-being of an individual, or in fact to maintain the normal body processes, proteins of sufficient quantity and quality are absolutely essential. The proteins normally occurring in the human dietary are of a quite varied nature and are derived from both the animal and vegetable kingdoms. Those foods which contain the largest proportion of protein and are ordinarily referred to as protein-rich foods are obtained largely from the animal kingdom and include such food materials as meats, eggs, and milk.

[1] Prepared under the direction of C. F. Langworthy, Chief, Office of Home Economics.

NOTE.—This bulletin records studies of the digestibility of protein supplied by soy-bean and peanut press-cake flours. It is primarily of interest to students and investigators of food problems.

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The many studies which have been made to determine the actual importance for dietary purposes of the proteins supplied by meats, eggs, and milk show quite conclusively that these proteins are of high biologic value. Unfortunately the supply of these food materials is becoming constantly less adequate to meet the needs of the very rapidly increasing population of this country. Furthermore, these foods are relatively expensive, and consequently can not be eaten as freely as formerly by those of small incomes. As a result of these conditions, students of nutrition have given considerable attention to the possibility of replacing animal proteins with vegetable proteins, and as a consequence the demand for vegetable foods which supply proteins that are of value for human food is steadily increasing. The cereals which contain relatively small amounts of protein are already so extensively used that as a group they now supply nearly one-half of the total protein of the average American diet. While practically all of the common vegetable foods contain protein, the amount present in foods of vegetable origin is small except in the case of the legumes, which may be classed as protein-rich food. Accordingly it appears that a more extensive use of legumes as a source of protein is to be desired. Those legumes most commonly used in this country are the well-known navy beans, red kidney, and lima beans, the garden pea, frijoles, pinto beans, and several varieties of cowpeas. Many studies have been made of the nutritive value and possible uses of these legumes, and several investigators have conducted experiments to determine their digestibility.

INVESTIGATIONS OF DIGESTIBILITY OF COMMON LEGUMES.

The digestibility of hulled peas cooked thoroughly until soft and passed through a sieve was determined by Rubner,[1] who found that the protein was 72 per cent digested. In a second experiment in which the subject ate 600 grams of peas per day the digestibility was found to be 83 per cent.

Malfatti [2] determined the digestibility of the protein supplied by a porridge made of split peas and found it to be 86 per cent digested.

Richter [3] reported that in an experiment in which the subject consumed 600 grams of purée of pea the protein was 90 per cent digested.

Snyder [4] conducted three experiments to determine the digestibility of pea protein and served a porridge (containing 82 per cent of water) made from dried peas. The porridge was eaten in conjunction with a basal ration consisting of rice, milk, and sugar; one-third of the protein of the diet was supplied by the peas. He found that the average digestibility of the pea protein was 80 per cent.

[1] Ztschr. Biol., 16 (1880), No. 1, pp. 119–128.
[2] Jahresber. Tier-Chem., 15 (1885), p. 412.
[3] Arch. Hyg., 46 (1903), No. 3, pp. 264–273.
[4] Minnesota Sta. Bul. 92 (1905), pp. 267–270.

Prausnitz[1] in a study of the digestibility of white beans cooked in salted water until soft found that the protein was approximately 70 per cent digested.

Snyder[2] studied tne digestibility of navy beans which were prepared by cooking for 20 minutes in boiling water containing bicarbonate of soda, removing the skins, and baking the hulled beans in the usual way. The results of three experiments indicated that bean protein was 80 per cent utilized.

Woods and Mansfield,[3] in a study of the digestibility of rations for lumbermen, included three experiments in which the ration contained beans, and found that the digestibility of the protein of the total diet was 85 per cent, and estimated that the digestibility of the bean protein was 78 per cent.

Wait[4] conducted a series of 72 experiments to determine the digestibility of kidney beans, white beans, and three varieties of cowpeas eaten in conjunction with a basal ration consisting of bread, milk, butter, pork, bananas, and sugar, and found that the coefficients of digestibility of the proteins were as follows: Kidney beans 77 per cent, white beans 78 per cent, Whippoorwill cowpeas 70 per cent, Clay cowpeas 74 per cent, and Lady cowpeas 83 per cent.

The general conclusion to be drawn from the experimental data cited above is that while the proteins of the more widely used legumes are quite well utilized by the human body, comparing very favorably in this respect with the cereal proteins, they are not as completely utilized as the proteins supplied by such animal foods as meats, eggs, and milk.

SOURCE AND AVAILABLE SUPPLY OF SOY-BEAN AND PEANUT PRESS CAKE.

Considerable interest has recently been aroused regarding the nutritive value of two legumes, soy beans, which as yet have not been extensively used in this country for food purposes, and peanuts, which, though well known and commonly eaten, have been used as a casual rather than a staple article of diet. It is of course true that soy beans have found limited use in some localities and that peanuts have been quite extensively used as a constituent of confectionery, as "salted peanuts," and more recently as "peanut butter," but neither has been very extensively used in the manner in which peas and beans appear in the dietary.

During very recent years the production of both these legumes has grown many fold. The increase in the culture of peanuts is due very likely to the fact that the boll weevil has made the growing of

[1] Ztschr. Biol., 26 (1890), pp. 227–232.
[2] Minnesota Sta. Bul. 74 (1902), p. 122.
[3] U. S. Dept. Agr., Office Expt. Stas. Bul. 149 (1904), pp. 60, pls. 4.
[4] U. S. Dept. Agr., Office Expt. Stas. Bul. 187 (1907), pp. 55.

cotton unprofitable in many sections of the South and peanuts are now grown as a supplementary crop. The recent increase in the production of soy beans has probably resulted primarily from the present great need of additional food materials for both human and animal consumption.

The present imperative demand for oils in the manufacture of explosives, coupled with the increased demand for oils for industrial and edible purposes, makes it highly probable that large quantities of soy beans and peanuts will be pressed in cottonseed-oil mills where the machinery is adapted for the expression of oil from these oil-bearing seeds as well as cotton seed.

It has been estimated[1] that 150,000 bushels, or 9,000,000 pounds of soy beans was pressed during the season (1917–18) in North Carolina alone, which produced more than 3,500 tons of press cake. In addition to the supply of domestic soy beans there are large quantities of beans which have been imported from other countries. It is also reported[2] that the greater portion of the present unusually large crop of peanuts will be pressed. The residue, which remains after most of the oil has been removed from soy beans and peanuts, commercially known as press cake, contains a high percentage of protein. Such press cake has been very largely used as stock feed and, because of its high nitrogen content, for fertilizing purposes. It is at once apparent, however, that if care were exercised in grading and cleaning sound soy beans and in shelling and sorting sound peanuts, and if they were pressed under sanitary conditions, the resulting press cakes should be of considerable value for use as human food, and especially as a source of protein. Furthermore, since the oil is not fully extracted by pressing, the "cakes" are also an important source of fat. Thus it would seem that the extensive studies which have already been made of the soy-bean and peanut proteins are of a very definite value and that further studies of the possible uses and value of high-grade soy-bean and peanut press cakes for human food are to be desired.

FACTORS CONSIDERED IN DETERMINING FOOD VALUE OF A PROTEIN.

In considering the value of any material as a source of protein for food purposes, at least three factors are ordinarily considered, namely, the amount, the quality, and the digestibility of the protein supplied by the material in question. The amount of the protein present in the material under consideration is determined by chemical analysis. The quality of the protein ordinarily is determined by either, or preferably both, of two methods: By ascertaining the number and nature of the amino acids making up the protein molecule,

[1] Personal communication, Forage Crop Investigations, Bureau Plant Industry.
[2] Personal communication, Bureau of Chemistry.

or by ascertaining the biologic value of the protein by means of carefully controlled feeding experiments with laboratory animals. Such experiments give data regarding the ability of a protein to support normal life processes, such as growth, maintenance, and reproduction. The amount of protein retained for body uses from the food eaten is generally determined by digestion experiments in which the protein under consideration appears as the sole or major portion of the protein in the diet.

The amount of protein supplied by soy-bean and peanut press-cake flours would obviously vary somewhat with the varieties of the legumes from which the flours were made and with the process of manufacture. Proximate analysis of the dried soy beans and peanuts shows them to have the following composition: Soy beans,[1] water 9.9 per cent, protein 36.5 per cent, fat 17.5 per cent, carbohydrates 30.8 per cent, and ash 5.3 per cent, the fuel value being approximately 1,950 calories per pound; peanuts[2], water 9.2 per cent, protein 25.8 per cent, fat 38.6 per cent, carbohydrates 24.4 per cent, and ash 2 per cent, the fuel value being approximately 2,480 calories per pound. When the oil is expressed from these legumes the percentage of protein is correspondingly increased and the resulting commercial press cakes ordinarily contain from 40 to 50 per cent of protein. The press cakes used in the study here reported, which were obtained by expressing oil from soy beans and peanuts in a small-sized expeller type of oil press, contained a larger amount of protein. But in any case the press cake should be classed as protein-rich material and on the basis of chemical analysis alone may well be considered as valuable food material. In order to ascertain the true value of these proteins for dietary purposes it is necessary to consider the factors referred to above, first, the quality of the protein as shown by the nature of the amino acids supplied and by its biologic value, and second, the digestibility of the protein.

THE AMINO ACIDS SUPPLIED BY SOY-BEAN AND PEANUT PROTEINS AS COMPARED WITH THOSE SUPPLIED BY COMMON CEREAL PROTEINS.

Since in the commercial utilization of soy-bean and peanut flours as human food these flours would, in all probability, be grouped with the cereal flours and meals, it is natural to compare the amino acids obtained from glycinin, the principal protein of soy beans, and arachin, the principal protein of peanuts, with gliadin, zein, rye-prolamin, oryzinin, and hordein, the principal proteins of wheat, corn, rye, rice, and barley, respectively.

[1] Personal communication, average of 121 analyses reported by Forage Crop Investigations, Bureau Plant Industry.

[2] U. S. Dept. Agr., Office Expt. Stas. Bul. 28 (1899), pp. 75.

A review of the literature of protein chemistry shows that while in general they are of a very complex structure the vegetable proteins yield on hydrolysis nearly all of the 16 amino acids which normally result from the decomposition of protein material. While all of these amino acids supply elements of value for food purposes, the results of carefully-controlled feeding experiments show conclusively that the dietary value of the different amino acids varies materially.

No résumé of the literature of protein and amino acid chemistry would be complete without special reference to the extensive investigations of Osborne [1] to whom the present interest in this subject is in no small measure due. In this brief discussion of amino acids it is impossible to more than refer to the investigations which have been carried out by Osborne et al.,[2] Henderson and Dean,[3] Kauffmann,[4] Cohnheim,[5] Abderhalden and coworkers,[6] Henriques,[7] Willcock and Hopkins,[8] Müller,[9] Rona and Müller,[10] Michaud,[11] McCollum et al.,[12] Folin and Denis,[13] Hart and assistants,[14] Kajiura,[15] Wheeler,[16] Underhill,[17] Nollau and Kastle,[18] Johns,[19] and Geiling,[20] to determine

[1] Amer. Chem. Jour., 13 (1891), pp. 327-347, 385-414; 14 (1892), pp. 212-224, 629-661, 662-689. Amer. Chem. Jour., 19 (1897), pp. 236, 237. Jour. Amer. Chem. Soc., 16 (1894), pp. 633-643, 703-712, 757-764; 17 (1895), pp. 429-448, 539-567, 587-603. 19 (1897), pp. 525-532. Ztschr. Physiol. Chem., 33 (1901), pp. 225-239, 240-292. Amer. Jour. Physiol., 5 (1901), pp. 180, 181. Jour. Amer. Chem. Soc., 24 (1902), pp. 140-167. Proc. Soc. Expt. Biol. and Med., 5 (1908), pp. 105-107. Science, n. ser., 28 (1908), pp. 417-427. The Vegetable Proteins [London], Longmans, Green and Co., 1909. Ergeb. Physiol., 10 (1910), pp. 47-215.

[2] Jour. Amer. Chem. Soc., 16 (1894), pp. 778-785; 18 (1896), pp. 536-542, 542-558, 575-582, 583-609, 609-623; 19 (1897), pp. 454-482, 482-487, 487-494, 494-500, 509-513; 20 (1898), pp. 348-362, 362-375, 393-405, 406-410, 410-419, 419-428; 22 (1900), pp. 379-413; 25 (1903), pp. 323-353, 474-478, 837-842, 842-848, 848-853, 853-855. Amer. Jour. Physiol., 13 (1905), pp. 35-44, 436-447; 14 (1905), pp. 151-171, 259-286; 15 (1906), pp. 333-356; 17 (1906), pp. 231-265; 18 (1907), pp. 123-128, 295-308; 19 (1907), pp. 53-60, 117-124, 468-474, 475-481; 20 (1908), pp. 470-476, 477-493, 494-499; 22 (1908), pp. 362-372, 423-432; 23 (1908), pp. 180-200. Jour. Biol. Chem., 3 (1907), pp. 213-217, 219-225; 5 (1908), pp. 187-195, 197-205. Amer. Chem. Jour., 15 (1893), pp. 392-471. Jour Biol. Chem., 10 (1911), No. 10, pp. 303-325; 12 (1912), No. 3, pp. 473-510, figs. 26; 13 (1912), No. 2, pp. 233-276, figs. 21; 14 (1913), No. 5, pp. 481-487; 17 (1914), No. 3, pp. 325-349, figs. 8; 18 (1914), No. 1, pp. 1-16, figs. 6; 20 (1915), No. 3, pp. 351-378, fig. 10; 22 (1915), No. 2, pp. 241-258, fig. 1; pp. 259-280; 25 (1916), No. 1, pp. 1-12, figs. 4; 29 (1917), No. 1, pp. 69-92, fig. 1.

[3] Amer. Jour. Physiol., 9 (1903), No. 6, pp. 386-390.

[4] Arch. Physiol. [Pflüger], 109 (1905), No. 9-10, pp. 440-465.

[5] Hoppe-Seyler's Ztschr. Physiol. Chem., 49 (1906), No. 1, pp. 64-71.

[6] Hoppe-Seyler's Ztschr. Physiol. Chem., 47 (1906), No. 4-6, pp. 354-358; 51 (1907), p. 232; 77 (1912), No. 1, pp. 22-58; 81 (1912), No. 4, pp. 323-328. Synthese der Zellbaustine in Pflanze und Tier. [Berlin, Julius Springer], 1912, p. 128.

[7] Hoppe-Seyler's Ztschr. Physiol. Chem., 49 (1906), No. 2-3, pp. 113-123; 60 (1909), No. 2, pp. 105-118.

[8] Jour. Physiol., 35 (1906), No. 1-2, pp. 88-102.

[9] Arch. Physiol. [Pfluger], 112 (1906), No. 5-6, pp. 245-291, pls. 2, fig. 1.

[10] Hoppe-Seyler's Ztschr. Physiol. Chem., 50 (1907), No. 4-5, pp. 263-280.

[11] Ztschr. Physiol. Chem., 59 (1909), No. 5-6, pp. 405-491.

[12] Amer. Jour Physiol., 29 (1911), No. 2, pp. 215-237. Jour. Biol. Chem., 19 (1914), No. 3, pp. 323-333; 2. (1915), No. 1, pp. 181-230, figs. 42; 20 (1915), No. 3, pp. 415-428, figs. 12; 28 (1916), No. 1, pp. 153-165, figs. 10, No. 1, pp. 211-229, figs. 17; No. 2, pp. 483-500, pl. 1, figs. 12.

[13] Jour. Biol. Chem., 11 (1912), No. 1, pp. 87-95.

[14] Jour. Biol. Chem., 13 (1912), No. 2, pp. 133-153, figs. 4; 19 (1914), No. 3, pp. 373-395, pl. 1, figs. 11. Wisconsin Sta. Research Bul. 17 (1911), pp. 205, pls. 19. Jour. Biol. Chem., 25 (1916), No. 2, pp. 239-260, pls. 9, figs. 9; 29 (1917), No. 1, pp. 57-68, pl. 1.

[15] Bio-Chem. Jour., 6 (1912), pp. 171-181.

[16] Jour. Expt. Zool., 15 (1913), pp. 209-223.

[17] The Physiology of the Amino Acids, F. P. Underhill, New Haven: Yale Univ. Press, 1915, pp. 169, pl. 1, figs. 13.

[18] Amer. Jour. Physiol., 39 (1915-16), No. 2, pp. 162-171, pls. 8. Kentucky Sta. Bul. 197 (1916), pp. 21, pls. 16.

[19] Jour. Biol. Chem., 28 (1916), No. 1, pp. 59-65, 67-75, 77-87.

[20] Jour. Biol. Chem., 31 (1917), No. 1, pp. 173-199.

the nature and nutritive value of proteins, especial attention being given to the amino acids supplied. While it was found that under some conditions tyrosine, cystine, arginine, histidine, glutamic and aspartic acids may act as limiting factors in the diet, it seems to be very generally recognized by these students of nutrition that the two amino acids, lysine and tryptophane, are of especial importance in the dietary, lysine being essential for "growth" and tryptophane essential for "maintenance." In view of these conclusions it appears desirable to compare the amino acids resulting from the hydrolysis of soy-bean and peanut proteins with those obtained by the hydrolysis of the common cereal proteins. The amounts of amino acids resulting from the hydrolysis of the principal proteins of some common cereals are brought together in the following table for comparison with those obtained by hydrolyzing glycinin and arachin:

Amino acids resulting from hydrolysis of proteins of cereals.

Amino acids.	Gliadin, wheat.	Zein,[3] corn.	Rye,[4] prolamin.	Oryzinin, rice.	Hordein,[7] barley.	Glycinin,[8] soy bean.	Arachin,[9] peanut.
Glycine	[1] 0.00	0.00	0.13	[5](?)	0.00	0.97	0.00
Alanine	[1] 2.00	9.79	1.33	[5] 3.7	.43	Not isolated.	4.11
Valine	[1] 3.34	1.88	Not isolated.	[5](?)	.13	.68	1.13
Luecine	[1] 6.62	19.55	6.30	[5] 14.3	5.67	8.45	3.88
Proline	[1] 13.22	9.04	9.82	[5] 3.3	13.73	3.78	1.37
Phenylalanine	[1] 2.35	6.55	2.70	[5] 2.0	5.03	3.86	2.60
Aspartic acid	[1] .58	1.71	.25	[5] .4	Not isolated.	3.89	5.25
Glutamic acid	[1] 43.66	26.17	38.05	[5] 14.5	43.20	19.46	16.69
Serine	[1] .13	1.02	.06	([5])	Not isolated.	Not isolated.	Not isolated.
Tyrosine	[1] 1.20	3.55	1.19	[5] .5	1.67	1.86	5.50
Cystine	[1] .45	.....	Not estimated.	[6] 1.26	Not estimated.	.....	.85
Arginine	[1] 3.16	1.55	2.22	[6] 9.15	2.16	5.12	13.51
Histidine	[2] 2.19	.82	.39	[6] 3.32	1.28	1.39	1.88
Lysine	[2] 1.21	.00	.00	[6] 4.26	.00	2.71	4.98
Ammonia	[1] 5.22	3.64	5.11	[6] 3.23	4.87	2.56	2.03
Tryptophane	[1] 1.00	.00	Present.	([6])	Present.	Present.	Present.

[1] Jour. Biol. Chem., 9 (1911), No. 5, p. 426.
[2] Jour. Biol. Chem., 22 (1915), No. 2, p. 261.
[3] Amer. Jour. Physiol., 26 (1910), No. 4, p. 304.
[4] Osborne, Ergeb. Physiol., 10 (1910), p. 86. (In the absence of a name for rye protein, Osborne referred to the alcohol soluble protein as rye prolamin.)
[5] Osborne, Ergeb. Physiol., 10 (1910), p. 112.
[6] Jour. Biol. Chem., 22 (1915), No. 2, p. 275.
[7] Osborne, Ergeb. Physiol., 10 (1910), p. 90
[8] Osborne, Ergeb. Physiol., 10 (1910), p. 132.
[9] C. O. Johns and D. B. Jones. To be published in the Journal of Biological Chemistry.

It will be noted on referring to the above table that the earlier analyses of gliadin, zein, rye-prolamin, oryzinin, and hordein indicated that these proteins supplied little if any lysine and tryptophane. In the more recent studies of oryzinin and gliadin it was found that on hydrolysis these proteins yield appreciable amounts of lysine. An unpublished investigation by C. O. Johns and A. J. Finks, Bureau of Chemistry, shows that hordein on hydrolysis yields approximately the

same amount of lysine as gliadin. However, the amount of these cereal proteins in some of the cereals is insufficient to supply adequate amounts of the essential amino acids, whereas soy beans and peanuts are rich in glycinin and arachin which yield a high percentage of lysine. In considering the dietary value of glycinin and arachin, from the standpoint of lysine and tryptophane, the consensus of opinion of biochemists seems to be well summed up in the conclusions of Osborne and Mendel [1] who state "We have shown that growth does not occur when lysine is lacking from the diet but takes place promptly on adding this amino acid to the otherwise adequate food," and in the conclusions expressed by Abderhalden,[2] who says that tryptophane is an indispensable component in the dietary.

It may also be noted, in discussing the relative nutritive value of proteins as regards the presence or absence of lysine and tryptophane, that Osborne and Mendel[3] state that lysine must be present in the diet since "the animal organism apparently can not synthesize lysine." These authors [4] also state that "Tryptophane can not be synthesized by the animal cells." Accordingly, a theoretical consideration of the relative nutritive value of soy-bean and peanut proteins, based upon their amino-acid content alone would indicate that glycinin and arachin possessed a greater dietary value than the principal proteins supplied by the common cereals.

BIOLOGIC VALUE OF SOY-BEAN AND PEANUT PROTEINS AS COMPARED WITH THAT OF COMMON CEREAL PROTEINS.

Feeding experiments have been made by a number of investigators for the purpose of securing data regarding the relative biological value of proteins supplied by some of the cereals referred to above. Willcock and Hopkins [5] state that "loss of weight begins the moment it [zein] forms the sole nitrogenous supply." Osborne and Mendel [6] report "We have now accumulated the results of a large experience in feeding zein, with the uniform consequence of decline when this protein forms the sole nitrogenous component of the dietary." These results have been confirmed by Wheeler [7] in studies with rats and later by Hart and McCollum,[8] who report that young pigs can not grow when the maize kernel is the sole source of nutriment. Hogan [9] conducted experiments to determine the value of corn protein, zein, when fed as the sole source of protein, and concluded that trypto-

[1] Jour. Biol. Chem., 25 (1916), No. 1, p. 2, figs. 4.
[2] Hoppe-Seyler's Ztschr. Physiol. Chem., 96 (1915), No. 1-2, pp. 1-147.
[3] Jour. Biol. Chem., 17 (1914), No. 3, p. 334.
[4] Ibid., p. 328.
[5] Jour. Physiol., 35 (1906), No. 1-2, p. 100.
[6] Jour. Biol. Chem., 17 (1914), No. 3, p. 338.
[7] Jour. Expt. Zool., 15 (1913), No. 2, pp. 209-223.
[8] Jour. Biol. Chem., 19 (1914), No. 3, pp. 373-395, pls. 2, figs. 11.
[9] Jour. Biol. Chem., 29 (1917), No. 3, pp. 485-493, figs. 3.

phane was the first limiting factor and lysine the second when all other factors known to be essential to the dietary have been supplied.

The nutritive value of the principal protein of wheat, gliadin, has also been carefully studied. Osborne and Mendel [1] found that "in order to promote the growth of experimental animals it is necessary to supplement gliadin with lysine."

Hart and McCollum [2] report "It is evident that the whole-wheat grain will not sustain growth and even leads to physiological disturbances when continued as the sole source of nutrients for but a short span of the entire period of growth." In a later paper Hart, McCollum, Steenbock, and Humphrey [3] conclude that an exclusive diet of wheat grain and wheat straw is wholly inadequate with heifers for reproduction and in some instances for continued growth.

The proteins of rye, rice, and barley have received much less attention by investgators than those of wheat and corn. It appears that while rice and barley supply small amounts of total protein, orzinin and hordein supply relatively large amounts of lysine. Osborne, Van Slyke, Leavenworth, and Vinograd [4] in comparing the basic substances yielded by the proteins of the endosperm of wheat (lysine 1.58), maize (lysine 0.97), and rice (lysine 4.26) with the figures reported by Thomas [5] for the percentage of assimilable nitrogen 40 per cent, 29 per cent, and 88 per cent, respectively, say "It is rather striking that the figures for the utilizability of these proteins correspond so closely with the lysine which they yield."

Buckner, Nollau, and Kastle [6] in experiments with chickens included a diet in which both barley and rice were fed in conjunction with hominy, oats, and gluten, and were of the opinion that the unsatisfactory growth which resulted could be attributed to the low lysine content of the diet, which probably means that only small quantities of rice were eaten. Osborne and Mendel report feeding experiments with rats in which concentrated oat, rice, and barley proteins were added to an otherwise adequate diet. They state [7] that "the total proteins of rice and barley in contrast with maize and oats, when furnished in diets containing 16 to 17 per cent of protein, supply enough of all the amino acids essential for growth."

It is interesting to compare these conclusions regarding the value of the cereal proteins with the conclusions reported regarding the value of soy-bean and peanut proteins. In a study of the relative value of some common proteins as supplements to corn gluten Os-

[1] Jour. Biol. Chem., 17 (1914), No. 3, pp. 325–349, figs. 8.
[2] Jour. Biol. Chem., 19 (1914), No. 3, p. 276.
[3] Loc. cit.
[4] Jour. Biol. Chem., 22 (1915), No. 2, p. 276.
[5] Arch. Anat. u. Physiol., Physiol. Abt., 1909, pp. 257, 259, 261.
[6] Amer. Jour. Physiol., 39 (1916), No. 2, pp. 162–171.
[7] Jour. Biol. Chem., 34 (1918), No. 3, p. 531.

borne and Mendel [1] included experiments with a commercial soy-bean flour and a peanut meal (prepared by grinding peanuts from which the oil had been extracted) in a series containing such materials as casein, lactalbumin, edestin, cottonseed protein, fish-meat meal, corn-oil cake, "vegetable-albumin flour" (largely gliadin), brewers' grains (largely residues of corn and barley proteins), and pea meal. The authors state, "An inspection of these tables shows that lactalbumin is the most efficient supplement—those which are equally efficient are milk albumin and soy-bean flour." The gain in weight reported for the experimental animals which were fed a diet which included the peanut meal indicated that this material ranks high as a supplement to corn gluten. As a result of these facts the authors conclude that "The efficiency of these supplements presumably depends essentially upon their relative content of lysine and tryptophane."

Osborne and Mendel report [2] in a study of the relative values for functions of growth of isolated proteins included in a diet consisting of an isolated protein, protein-free milk, starch, agar, and fat that they were able to secure active growth with casein, ovalbumin, lactalbumin, edestin, glutenin, and glycinin (soy-bean protein), and that they secured little or no growth with gliadin, hordein, and zein.

Osborne and Mendel [3] in a report of results of experiments made with rats say "On diets containing either the soy-bean meal or the commercial soy-cake meal, together with fats and "Protein-free milk" or our "artificial" salt mixture, several broods of vigorous young have been produced, and these young have grown normally on diets the same as those on which their parents were raised. This is a further demonstration of the nutritive efficiency of this legume, in striking contrast with the adverse results obtained with kidney beans and garden peas."

Daniels and Nichols [4] as the result of experiments with rats conducted to determine the biologic value of protein supplied by soy beans which had been cooked 30–40 minutes under 15 pounds pressure concluded that—

> The value of the protein of the soy bean has been demonstrated in all of our experiments. That animals fed rations containing 15.6 and 18.7 per cent of protein obtained solely from the soy bean have grown normally and in the latter case * * * [with the larger percentage of soy-bean protein] have produced successive litters of young, which in turn have reproduced, is sufficient evidence that the protein of the soy bean fulfills all physiologic requirements. The protein of the soy bean appears to be quite as valuable as the casein of milk. These findings are somewhat surprising in view of the fact that the protein of other legumens, namely peas and white beans, has been found wanting.

[1] Jour. Biol. Chem., 29 (1917), No. 1, p. 77.
[2] Carnegie Inst. Washington Pub. No. 156, pt. 2, p. 83.
[3] Jour. Biol. Chem., 32 (1917), No. 3, p. 375.
[4] Jour. Biol. Chem., 32 (1917), No. 1, p. 95.

While several investigators are giving attention to the nature and value of the peanut proteins, as yet little information has been reported regarding the biologic value of these proteins. Daniels and Loughlin [1] have recently reported a study of two peanut meals; one of which was ground roasted peanuts which contained the normal amount of peanut oil, the second was ground press cake which contained a relatively small amount of peanut oil. Regarding the biologic value of peanut proteins the authors state—

> Rations consisting of 67.5 grams of peanut meal, supplying 18 per cent protein, 10 grams of lard, 5 grams of butter fat, 11.4 grams of cornstarch, and 5.09 grams of suitable inorganic material proved satisfactory in every way. The curves of growth * * * [as one of the charts accompanying the paper shows] in all cases were similar to those generally considered to be normal. Reproduction occurred at frequent intervals and three generations were obtained. Good growth was secured also with a ration supplying 15 per cent protein from the peanut meal. The proteins of peanuts are comparable to those of the soy bean, since it has been shown that both legumes supply the essential amino acids in sufficient amounts for normal growth and reproduction.

In discussing the value of soy-bean flour it should also be noted that this material is especially valuable for food purposes since it supplies the water-soluble and to a limited extent the fat-soluble accessories essential in a complete diet. In this connection Daniels and Nichols [2] say:

> It contains a high percentage of a physiologically good protein, a considerable amount of energy-yielding material in the form of fat and carbohydrate, and a fairly liberal supply of the fat-soluble food accessory, as well as of the water-soluble growth determinant.

And Osborne and Mendel [3] state that—

> So far as we are aware the soy bean is the only seed hitherto investigated, with the possible exception of flax and millet, which contains both the water-soluble and [in limited quantity] the fat-soluble unidentified dietary essentials or vitamins. This fact, taken with the high physiological value of the protein, lends a unique significance to the use of the soy bean as food.

Referring to the presence of the fat-soluble and water-soluble food accessories in peanut meal Daniels and Loughlin [4] say:

> That peanuts are lacking in the fat-soluble food accessory has been shown by the behavior of animals which were given rations containing no butter fat * * *. Since all the animals receiving the 5 per cent butter-fat ration were normal in every respect, proof is furnished for the presence of a considerable amount of the water-soluble food accessory in the diets. When the peanuts formed 56 per cent of the ration, there was sufficient water-soluble B for the experimental animals. Like the soy bean, it needs only to have added suitable inorganic material and some of the fat-soluble food accessory to make it a complete food.

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[1] Jour. Biol. Chem., 32 (1918), No. 2, p. 296.
[2] Jour. Biol. Chem., 32 (1917), No. 1, p. 96.
[3] Jour. Biol. Chem., 32 (1917), No. 3, p. 376.
[4] Loc. cit.

Osborne and Mendel[1] also report that they have been able to demonstrate the presence of the water-soluble food accessory in peanut meal.

In summarizing the studies of the nature and value of soy-bean and peanut proteins, referred to above, it appears first that chemical analysis of glycinin and arachin shows them to be relatively rich in lysine and tryptophane, amino acids essential for growth and maintenance, and second that studies of their biologic value show them to be more efficient proteins than those supplied by the common cereals or many of the common legumes. It appears then from these facts that soy-bean and peanut proteins have a high nutritive value and that further studies of their value in the human dietary are to be desired.

THE DIGESTIBILITY OF SOY-BEAN AND PEANUT PROTEINS.

This investigation was undertaken for the purpose of determining the digestibility of these proteins by normal individuals when eaten as a constituent of a simple mixed diet. It is of course recognized that the oil remaining in the soy-bean and peanut flours contributes to the food value of these flours, but no special attention is given to these oils in this study since previous studies of peanut [2] and soy-bean oils [3] have shown that both are very well utilized by the human body.

PREPARATION OF SOY-BEAN AND PEANUT PRESS-CAKE FLOURS.[4]

The soy-bean flour used in the experiments which follow was prepared by expelling the oil from 2 bushels of well-cleaned Mammoth Yellow soy beans which had been grown under controlled experimental conditions by Forage Crop Investigations of the Bureau of Plant Industry. In order to secure a more nearly complete removal of the oil than is usual, the cake was pressed a second time. The press cake thus obtained was of a yellow color and retained about 8 per cent of oil. It was ground in a small-sized burr mill until all of the meal passed through a millimeter sieve. Through the courtesy of H. S. Bailey, of the Bureau of Chemistry, it was possible to prepare both the soy-bean and peanut flours under conditions approximating those of the commercial oil mill, using for this purpose a continuous process expeller type of oil-expressing machine.

In order to secure data relative to the fineness of this flour, a sample was bolted, and it was found that 53 per cent of the flour remained on the 40-mesh sieve, 23 per cent remained on the 70-mesh sieve, 9 per cent remained on the 90-mesh sieve, 3 per cent remained

[1] Jour. Biol. Chem., 32 (1917), No. 3, p. 310.
[2] U. S. Dept. Agr. Bul. 505 (1917), p. 18.
[3] U. S. Dept. Agr. Bul., 687 (1918), p. 6.
[4] In this paper the term "flour" is used without reference to the coarseness of the ground soy-bean and peanut press cakes.

on the 109-mesh sieve, and 12 per cent passed through the 109-mesh sieve. In view of the high protein content of the soy-bean press cake it seemed of interest to determine whether the distribution of nitrogen was uniform for the fractions remaining on the different-sized sieves. For this purpose a press cake which had been ground to duplicate the fineness of commercial soy-bean flour was chosen. That portion remaining on the 40-mesh sieve contained 5.95 per cent of nitrogen, that on the 70-mesh sieve 7.62 per cent, that on the 90-mesh sieve 8.06 per cent, that on the 109-mesh sieve 8.21 per cent, and the portion that passed through the 109-mesh sieve contained 8.32 per cent of nitrogen.

As often prepared in the commercial expression of peanut oil, the peanut press cake contains, in addition to peanut kernels, the shells and the thin red skin which surrounds the kernel. Consequently such commercial press cake, though suited for use as stock feed or fertilizer, is not suitable for food purposes; especially is this true when moldy or unsound peanuts are included, when the shells are dirty, or when the oil is not expressed under sanitary conditions. In the commercial preparation of "salted peanuts" clean shelled peanuts of good quality are "blanched" by subjecting them to an atmosphere of live steam just long enough to loosen the skin surrounding the kernels but not long enough to allow the kernels to absorb any appreciable amount of water vapor. A subsequent agitation of these kernels in a container provided with either a suction or a blower separates the skins from the kernels. The expression of oil by the cold process from such kernels produces a virgin oil and a high-grade press cake rich in protein. If shelled peanuts, from which the surrounding skin has not been removed, are pressed the resulting flour, though satisfactory for food purposes, is of a reddish tinge and has a somewhat different and less-pleasing flavor than that of the flour prepared from blanched kernels.

In the study here reported of the digestibility of the proteins supplied by peanut flour a series of experiments was made with each of these types of flours. The peanut flour used in the first series of experiments was prepared by expressing the oil from blanched, roasted peanuts and grinding the resulting press cake. The flour used in the second series of experiments was prepared by the cold expression of shelled raw peanuts from which the red skin had not been removed. The reddish flour obtained did not possess the rich nut-like odor of that obtained from roasted kernels. A sample of the flour from the unroasted peanuts was bolted and sieved to secure data regarding its fineness, and it was found that 54 per cent of the flour remained on the 40-mesh sieve, 23 per cent on the 70-mesh sieve, 13 per cent on the 90-mesh sieve, 5 per cent on the 109-mesh sieve, and 5 per cent passed through the latter sieve.

THE SUBJECTS OF THE DIGESTION EXPERIMENTS.

Seven subjects with previous experience in experiments which were made to determine the digestibility of some edible fats assisted in this investigation. In general they were students of dental or medical schools and were of normal health and appetite. Their ages ranged from 20 to 40 years and their activities were such that they would be classified as moderately-active persons. As is always the case, they were instructed to exercise care in saving all uneaten portions of the food, in separating and collecting the feces, and in submitting reports concerning their physical condition before, after, and during the experimental period. Inasmuch as all seemed in their usual good physical condition throughout the entire time of the experiments, no detailed discussion of these reports is given.

PREPARATION OF EXPERIMENTAL DIETS.

As in all studies of this character, it was desired that the nutrient under consideration, in this case the proteins supplied by soy-bean and peanut flours, should comprise as large a portion as possible of the total protein of the diet. It is essential that the foods studied be prepared in an acceptable form and accordingly preliminary tests were made of a number of methods of preparing these flours for eating. As a result of these tests it appeared that "tea biscuits" similar to those so commonly made with wheat flour were well adapted to this purpose. The recipe used follows:

RECIPE FOR BISCUITS.

16 cups flour mixture.
16 tablespoons lard.
12 teaspoons salt.
10 tablespoons baking powder.
6 cups water.

In the soy-bean experiments the flour mixture was prepared by mixing equal portions of wheat flour and soy-bean flour. In the experiments with the peanut flour made from roasted kernels, the proportion was two-thirds wheat flour and one-third peanut flour, and in the experiments with peanut flour made from the raw kernels from which the red skin was not removed, the proportion was one to one. The wheat flour used in all cases was a commercial brand of patent flour.

Biscuits made with flour and soy-bean flour or peanut flour one to one were satisfactory when only one-half or three-fourths inch in thickness; thicker biscuits being very often rather "heavy," no doubt because the amount of gluten in the flour mixture was rather small. It was found that if the biscuits were very thoroughly baked (though not scorched) they possessed a much better flavor than those not so well done.

In order that the major portion of the protein supplied by the experimental diet should be derived from the soy-bean and peanut flours, the accessory foods were chosen to supply only a minimum of protein, and included oranges, butter, and tea or coffee with sugar if desired. Since the subjects ate very generous amounts of the biscuits but had a very limited diet in other respects it was thought that they would use large quantities of butter. It was found, however, that though they could have all they wanted they ate on an average only about 56 grams daily.

DETAILS OF THE EXPERIMENTS.

In this study of the digestibility of the proteins supplied by soy-bean and peanut flours the methods which were employed were very similar to those followed in the study of the grain sorghums.[1] The usual 3-day or 9-meal experimental period was considered satisfactory for this study. No attempt was made to maintain a uniform body weight of the subjects or to maintain nitrogen equilibrium during the period. As is usual in such cases, sufficient food material was prepared at one time to supply all the subjects for the entire experimental period, representative samples of all the foods being retained for analysis. These samples and those of the air-dried feces of each subject resulting from the experimental diet were analyzed in the usual way. The differences between the amounts of protein, fat, and carbohydrates present in the foods and in the feces were taken to represent the amounts of these constituents digested. This method of procedure gives data regarding the digestibility of protein, fat, and carbohydrate supplied by the entire diet. Since in this study the coefficients of digestibility of the soy-bean and peanut proteins are of special interest they have been estimated by making allowance for the undigested protein material occurring in the diet. The method followed in estimating the digestibility of the proteins supplied by the soy beans and peanuts is indicated by the following equations:

[Weight of protein in accessory food materials] × [Percentage of undigested protein in each] = [Protein in feces from food other than bread].

[Total protein in feces] − [Protein in feces from food other than bread] = [Weight of undigested bread protein.]

[Weight of protein in bread] − [Weight of undigested bread protein] ÷ [Weight of protein in bread] = [Estimated percentage of availability of bread protein.]

In determining the amount of undigested protein present in the accessory food materials in the experimental diet it was assumed that

[1] U. S. Dept. Agr. Bul. 470 (1916), pp. 30.

the protein[1] of wheat flour was 93.8 per cent digested, the protein[2] of orange 85 per cent, and the protein[2] of butter was 97 per cent digested.

It is, of course, recognized that the calculated values so obtained, for a special food, in this case soy-bean and peanut proteins, are probably somewhat low, since they include the errors due to considering all fecal nitrogen not resulting from the accessory foods as undigested soy-bean or peanut nitrogen, whereas fecal nitrogen, as has been pointed out by Woods and Merrill,[3] Crowther and Woodman,[4] and others, is derived in part at least from bile residues, epithelial waste, stomach residues, mucus, and saliva. It is not believed, however, that in this instance the error occasioned by the inability to correct for this factor is significant, especially in view of the unusually large quantities of soy-bean or peanut proteins consumed.

THE DIGESTIBILITY OF PROTEIN SUPPLIED BY SOY-BEAN PRESS-CAKE FLOUR.

In spite of the very extensive use of soy beans by the oriental peoples there appears to be little experimental data reported regarding the digestibility of the proteins supplied by this protein-rich legume. However, the long use of the soy bean as a staple article of the diet by the Japanese and Chinese offers sufficient evidence that soy-bean protein is well tolerated by the human body. Oshima in a summary of Japanese nutrition investigations, which includes much interesting information regarding the digestibility of preparations of legumes in common use in Japan, reports three experiments[5] in which the subjects ate approximately 200 grams of tofu (soy-bean curd) daily in conjunction with cooked rice. The average digestibility of the total protein supplied by these diets, of which 83 per cent was soy-bean protein, was 95 per cent.

Few studies of the digestibility of soy-bean protein have been made in this country. Mendel and Fine report[6] an experiment of six days' duration in which soy beans supplied 90.5 per cent of the total nitrogen intake, the basal ration consisting of tomatoes, apples, oranges, milk, sugar, and butter. The soy beans were boiled in water for one-half hour and the tomatoes thoroughly incorporated with the resulting mush which had been salted to taste. The total nitrogen supplied by the diet was 85.3 per cent digested. The subject reported that he was in excellent condition throughout the whole experiment. Defecation was regular and no physiological disturbances were experienced. The same authors conducted two series of

[1] U. S. Dept. Agr., Office Expt. Stas. Bul. 143 (1904), p. 32.
[2] Connecticut Storr's Sta. Rpt. 1899, p. 104.
[3] U. S. Dept. Agr., Office Expt. Stas. Bul. 143 (1904), p. 57.
[4] Jour. Agr. Sci., 8 (1917), pp. 429–477, Part IV.
[5] U. S. Dept. Agr., Office Expt. Stas. Bul. 159 (1905), pp. 224.
[6] Jour. Biol. Chem., 10 (1911), pp. 433–458.

digestion experiments with laboratory animals (dogs). In the first series (three tests) the animals received a mush prepared by heating soy beans, lard, agar, bone ash, and water on a water bath for 4 to 6 hours. In the second series (nine tests) the animals were "subjected to a thorough treatment with indigestible nonnitrogenous materials, to remove, as far as possible, the accumulated intestinal débris," and were fed a mixture of soy beans, sugar, and lard which was allowed to stand in water overnight. During the first series the animals ate an average of 86 grams of soy beans daily and an average of 58 grams in the second series. The digestibility of the total nitrogen of the diet was for the first series 80 per cent and for the second 84 per cent.

In the present study the seven experiments conducted to determine the digestibility of the protein supplied by soy-bean flour were divided into two series, one of four and one of three tests. The interval between first and second series comprised a rest period of two days on an ordinary mixed diet followed by an experimental period of three days during which the digestibility of a vegetable fat was studied and this by a second rest period of four days on an ordinary mixed diet. The experimental conditions and the subjects were identical for both series of experiments. Four subjects living under normal conditions assisted in the experiments which are reported in the following tables:

Data of digestion experiments with soy-bean flour in a simple mixed diet.

Experiments, subjects, and diet.	Weight of foods.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrates.	Ash.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Experiment No. 669, subject A. F.:						
Biscuits containing soy-bean flour	1,396.0	456.1	254.8	129.1	497.8	58.2
Fruit	828.0	719.5	6.6	1.7	96.1	4.1
Butter	210.0	23.1	2.1	178.5	.....	6.3
Sugar	135.0	.....	.....	.....	135.0	.....
Total food consumed	2,569.0	1,198.7	263.5	309.3	728.9	68.6
Feces	84.0	.....	29.4	16.4	21.6	16.6
Amount utilized	.....	.....	234.1	292.9	707.3	52.0
Per cent utilized	.....	.....	88.8	94.7	97.0	75.8
Experiment No. 670, subject P. K.:						
Biscuits containing soy-bean flour	1,571.0	513.3	286.7	145.3	560.2	65.5
Fruit	410.0	356.3	3.3	.8	47.6	2.0
Butter	316.0	34.8	3.1	268.6	.....	9.5
Sugar	181.0	.....	.....	.....	181.0	.....
Total food consumed	2,478.0	904.4	293.1	414.7	788.8	77.0
Feces	142.0	.....	53.4	33.4	36.3	18.9
Amount utilized	.....	.....	239.7	381.3	752.5	58.1
Per cent utilized	.....	.....	81.8	91.9	95.4	75.5
Experiment No. 671, subject J. C. M.:						
Biscuits containing soy-bean flour	1,178.0	384.8	215.0	109.0	420.1	49.1
Fruit	446.0	387.6	3.6	.9	51.7	2.2
Butter	192.0	21.1	1.9	163.2	.....	5.8
Sugar	276.0	.....	.....	.....	276.0	.....
Total food consumed	2,092.0	793.5	220.5	273.1	747.8	57.1
Feces	94.0	.....	36.0	13.4	30.4	14.2
Amount utilized	.....	.....	184.5	259.7	717.4	42.9
Per cent utilized	.....	.....	83.7	95.1	95.9	75.1

Data of digestion experiments with soy-bean flour in a simple mixed diet—Continued.

Experiments, subjects, and diet.	Weight of foods.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 672, subject A. A. R.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Biscuits containing soy-bean flour	1,296.0	423.4	236.5	119.9	462.2	54.0
Fruit	893.0	776.0	7.1	1.8	103.6	4.5
Butter	43.0	4.7	.4	36.6	.....	1.3
Sugar	154.0	.....	.....	.....	154.0	.....
Total food consumed	2,386.0	1,204.1	244.0	158.3	719.8	59.8
Feces	77.0	.....	28.5	12.1	25.9	10.5
Amount utilized	.....	.....	215.5	146.2	693.9	49.3
Per cent utilized	.....	.....	88.3	92.4	96.4	82.4
Experiment No. 678, subject P. K.:						
Biscuits containing soy-bean flour	1,629.0	528.0	287.7	83.4	653.4	76.5
Fruit	413.0	358.9	3.3	.8	47.9	2.1
Butter	400.0	44.0	4.0	340.0	.....	12.0
Sugar	246.0	.....	.....	.....	246.0	.....
Total food consumed	2,688.0	930.9	295.0	424.2	947.3	90.6
Feces	76.0	.....	27.1	13.7	22.3	12.9
Amount utilized	.....	.....	267.9	410.5	925.0	77.7
Per cent utilized	.....	.....	90.8	96.8	97.6	85.8
Experiment No. 679, subject J. C. M.:						
Biscuits containing soy-bean flour	1,245.0	403.5	219.9	63.7	499.4	58.5
Fruit	466.0	405.0	3.7	.9	54.1	2.3
Butter	206.0	22.6	2.1	175.1	.....	6.2
Sugar	257.0	.....	.....	.....	257.0	.....
Total food consumed	2,174.0	831.1	225.7	239.7	810.5	67.0
Feces	85.0	.....	30.3	10.5	30.4	13.8
Amount utilized	.....	.....	195.4	229.2	780.1	53.2
Per cent utilized	.....	.....	86.6	95.6	96.2	79.4
Experiment No. 680, subject A. A. R.:						
Biscuits containing soy-bean flour	1,239.0	401.6	218.8	63.4	497.0	58.2
Fruit	1,384.0	1,202.7	11.1	2.8	160.5	6.9
Butter	46.0	5.1	.4	39.1	.....	1.4
Sugar	230.0	.....	.....	.....	230.0	.....
Total food consumed	2,899.0	1,609.4	230.3	105.3	887.5	66.5
Feces	95.0	.....	31.6	7.8	40.5	15.1
Amount utilized	.....	.....	198.7	97.5	847.0	51.4
Per cent utilized	.....	.....	86.3	92.6	95.4	77.3
Average food consumed per subject per day	823.1	355.8	84.4	91.6	268.1	23.2

Summary of digestion experiments with soy-bean flour in a simple mixed diet.

Experiment No.	Subject.	Digestibility of entire ration.				Estimated digestibility of soy-bean protein alone.
		Protein.	Fat.	Carbohydrates.	Ash.	
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
669	A. F.	88.8	94.7	97.0	75.8	88.0
670	P. K.	81.8	91.9	95.4	75.5	79.4
671	J. C. M.	83.7	95.1	95.9	75.1	81.6
672	A. A. R.	88.3	92.4	96.4	82.4	87.5
678	P. K.	90.8	96.8	97.6	85.8	90.2
679	J. C. M.	86.6	95.6	96.2	79.4	85.2
680	A. A. R.	86.3	92.6	95.4	77.3	85.0
Average		86.6	94.2	96.3	78.8	85.3

In the experiments with soy-bean flour the subjects ate on an average 84 grams of protein, 92 grams of fat, and 268 grams of carbohydrate per man per day. The coefficients of digestibility for the entire diet were, for protein 86.6 per cent, for fats 94.2 per cent, and for carbohydrate 96.3 per cent. The digestibility of soy-bean protein was estimated to be 85.3 per cent. Referring to pages 2 and 3 it will be noted that the digestibility of the proteins of common legumes, as shown by numerous studies made by well-known investigators, is noticeably lower than this. It is quite possible that the method of preparation and of cooking may affect the digestibility to some extent, since in grinding the press cake the cells are without doubt quite thoroughly broken up. However, in those studies in which peas were served in the form of a purée the cells were also very thoroughly broken. The digestibility of soy-bean protein (85.3 per cent) compares very favorably with that of the common cereals.

Of the 84 grams of protein eaten daily 82 grams were supplied by the soy-bean biscuits. Since approximately 85 per cent of the total protein of the biscuits was soy-bean protein, the subjects ate on an average 70 grams of soy-bean protein daily. Inasmuch as none of the subjects reported any physiological disturbances as a result of this diet, it appears that soy-bean protein is well tolerated by the human body.

The results of the experiments in general indicate that protein supplied by soy-bean press cake (ground to flour) is well assimilated and is too valuable to be overlooked as a human food.

THE DIGESTIBILITY OF PROTEIN SUPPLIED BY PEANUT PRESS-CAKE FLOUR.

As previously noted on page 13, two types of peanut flour were used in these tests, namely, one made by grinding the press cake resulting from the expression of oil from roasted, degermed peanuts, and the other by grinding the press cake remaining after the expression of oil from raw shelled peanuts from which the red skin had not been removed. The roasted peanut flour was of a golden yellow color and that from the raw peanuts was of a decidedly red tinge. Seven experiments were made with flour made from roasted peanuts and four with flour made from raw peanuts. In the first series of experiments the "flour mixture" used for making the biscuits consisted of two parts wheat flour and one part peanut flour (roasted peanuts), and in the second series the "flour mixture" consisted of equal parts of wheat flour and peanut flour (raw peanuts). Since the same men served as subjects and uniform experimental conditions were maintained for both series, the results obtained should be directly comparable.

EXPERIMENTS WITH FLOUR MADE FROM ROASTED PEANUTS.

The results obtained in the seven experiments in which peanut flour made from roasted nuts was studied are reported in the following tables:

Data of digestion experiments with flour made from roasted peanuts in a simple mixed diet.

Experiments, subjects, and diet.	Weight of foods.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 618, subject P. K.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Biscuits containing peanut flour	1,229.0	333.9	168.3	101.5	572.5	52.8
Peanut oil	136.0	.....	.....	136.0	.....	.....
Fruit	755.0	656.1	6.0	1.5	87.6	3.8
Sugar	281.0	.....	.....	.....	281.0	.....
Total food consumed	2,401.0	990.0	174.3	239.0	941.1	56.6
Feces	29.0	.....	10.9	6.1	8.4	3.6
Amount utilized	.....	.....	163.4	232.9	932.7	53.0
Per cent utilized	.....	.....	93.7	97.4	99.1	93.6
Experiment No. 619, subject J. C. M.:						
Biscuits containing peanut flour	993.0	269.8	136.0	82.0	462.5	42.7
Peanut oil	89.0	.....	.....	89.0	.....	.....
Fruit	1,056.0	917.7	8.4	2.1	122.5	5.3
Sugar	192.0	.....	.....	.....	192.0	.....
Total food consumed	2,330.0	1,187.5	144.4	173.1	777.0	48.0
Feces	51.0	.....	19.5	8.5	15.5	7.5
Amount utilized	.....	.....	124.9	164.6	761.5	40.5
Per cent utilized	.....	.....	86.5	95.1	98.0	84.4
Experiment No. 620, subject C. J. W.:						
Biscuits containing peanut flour	1,188.0	322.8	162.6	98.1	553.4	51.1
Peanut oil	199.0	.....	.....	199.0	.....	.....
Fruit	751.0	652.6	6.0	1.5	87.1	3.8
Sugar	164.0	.....	.....	.....	164.0	.....
Total food consumed	2,302.0	975.4	168.6	298.6	804.5	54.9
Feces	80.0	.....	33.3	14.4	21.7	10.6
Amount utilized	.....	.....	135.3	284.2	782.8	44.3
Per cent utilized	.....	.....	80.2	95.2	97.3	80.7
Experiment No. 633, subject A. A. F.:						
Biscuits containing peanut flour	2,244.0	712.5	349.2	114.9	977.0	90.4
Fruit	762.0	662.2	6.1	1.5	88.4	3.8
Peanut oil	107.0	.....	.....	107.0	.....	.....
Sugar	233.0	.....	.....	.....	233.0	.....
Total food consumed	3,346.0	1,374.7	355.3	223.4	1,298.4	94.2
Feces	64.0	.....	23.2	11.2	21.6	8.0
Amount utilized	.....	.....	332.1	212.2	1,276.8	86.2
Per cent utilized	.....	.....	93.5	95.0	98.3	91.5
Experiment No. 634, subject P. K.:						
Biscuits containing peanut flour	1,923.0	610.5	299.2	98.5	837.3	77.5
Fruit	485.0	421.5	3.9	1.0	56.2	2.4
Peanut oil	224.0	.....	.....	224.0	.....	.....
Sugar	167.0	.....	.....	.....	167.0	.....
Total food consumed	2,799.0	1,032.0	303.1	323.5	1,060.5	79.9
Feces	85.0	.....	27.5	29.0	18.3	10.2
Amount utilized	.....	.....	275.6	294.5	1,042.2	69.7
Per cent utilized	.....	.....	90.9	91.0	98.3	87.2
Experiment No. 635, subject J. C. M.:						
Biscuits containing peanut flour	1,589.0	504.5	247.2	81.4	691.9	64.0
Fruit	869.0	755.2	7.0	1.7	100.8	4.3
Peanut oil	190.0	.....	.....	190.0	.....	.....
Sugar	197.0	.....	.....	.....	197.0	.....
Total food consumed	2,845.0	1,259.7	254.2	273.1	989.7	68.3
Feces	40.0	.....	16.8	5.3	11.7	6.2
Amount utilized	.....	.....	237.4	267.8	978.0	62.1
Per cent utilized	.....	.....	93.4	98.1	98.8	90.9

Data of digestion experiments with flour made from roasted peanuts in a simple mixed diet—Continued.

Experiments, subjects, and diet.	Weight of foods.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 636, subject C. J. W.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Biscuits containing peanut flour	1,928.0	612.1	300.0	98.7	839.5	77.7
Fruit	878.0	763.0	7.0	1.8	101.8	4.4
Peanut oil	203.0	.....	.....	203.0	.....	.....
Sugar	194.0	.....	.....	.....	194.0	.....
Total food consumed	3,203.0	1,375.1	307.0	303.5	1,135.3	82.1
Feces	63.0	.....	26.4	10.6	18.0	8.0
Amount utilized	.....	.....	280.6	292.9	1,117.3	74.1
Per cent utilized	.....	.....	91.4	96.5	98.4	90.3
Average food consumed per subject per day	915.5	390.2	81.3	87.3	333.6	23.0

Summary of digestion experiments with flour made from roasted peanuts in a simple mixed diet.

Experiment No.	Subject.	Digestibility of entire ration.				Estimated digestibility of peanut protein alone.
		Protein.	Fat.	Carbohydrates.	Ash.	
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
618	P. K.	93.7	97.4	99.1	93.6	93.5
619	J. C. M.	86.5	95.1	98.0	84.4	75.0
620	C. J. W.	80.2	95.2	97.3	80.7	60.7
633	A. A. F.	93.5	95.0	98.3	91.5	92.9
634	P. K.	90.9	91.0	98.3	87.2	86.9
635	J. C. M.	93.4	98.1	98.8	90.9	92.6
636	C. J. W.	91.4	96.5	98.4	90.3	87.9
Average		89.9	95.5	98.3	88.4	84.2

On an average the subjects ate 81 grams of protein, 87 grams of fat, and 334 grams of carbohydrate daily, which supplied about 2,445 calories. The coefficients of digestibility of these constituents supplied by the diet as a whole were found to be 89.9 per cent for protein, 95.5 per cent for fat, and 98.3 per cent for carbohydrate, indicating that the diet was quite well utilized. The above value for the digestibility of the total protein of the diet becomes 84.2 per cent for the digestibility of peanut protein alone when correction is applied for the undigested protein occurring in the accessory foods. The diet as a whole supplied 81 grams of protein daily, of which 79 grams were derived from the peanut-flour biscuits, and approximately 34 grams were obtained from the peanut flour. No physiological disturbances were noted by any of the subjects, indicating that this amount of peanut protein was well tolerated in these experiments.

In this series of experiments the subjects ate on their biscuits in place of butter peanut oil which was expressed from the blanched

peanuts from which the peanut flour was prepared. The average amount eaten was 55 grams daily; and apparently it was well digested, since the total fat of the diet—principally lard and peanut oil—was 95.5 per cent digested. This compares very favorably with the figures reported for the digestibility of lard [1] and peanut oil [2] as determined in earlier studies.

EXPERIMENTS WITH FLOUR MADE FROM RAW PEANUTS.

The data resulting from the four experiments made with peanut flour made from raw peanuts are summarized in the table which follows:

Data of digestion experiments with flour made from raw peanuts in a simple mixed diet.

Experiments, subject, and diet.	Weight of foods.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 696, subject P. K.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Biscuits containing peanut flour	1,571.0	384.4	386.9	238.2	480.0	81.5
Butter	337.0	37.1	3.4	286.4	.....	10.1
Fruit	390.0	338.9	3.1	.8	45.2	2.0
Sugar	224.0	.....	.....	.....	224.0	.....
Total food consumed	2,522.0	760.4	393.4	525.4	749.2	93.6
Feces	84.0	.....	35.4	15.5	20.4	12.7
Amount utilized	.....	.....	358.0	509.9	728.8	80.9
Per cent utilized	.....	.....	91.0	97.0	97.3	86.4
Experiment No. 697, subject J. C. M.:						
Biscuits containing peanut flour	1,168.0	285.8	287.6	177.1	356.9	60.6
Butter	246.0	27.0	2.5	209.1	.....	7.4
Fruit	795.0	690.8	6.4	1.6	92.2	4.0
Sugar	228.0	.....	.....	.....	228.0	.....
Total food consumed	2,437.0	1,003.6	296.5	387.8	677.1	72.0
Feces	69.0	.....	30.4	8.2	24.4	6.0
Amount utilized	.....	.....	266.1	379.6	652.7	66.0
Per cent utilized	.....	.....	89.7	97.9	96.4	91.7
Experiment No. 698, subject A. A. R.:						
Biscuits containing peanut flour	1,419.0	347.2	349.4	215.1	433.6	73.7
Butter	101.0	11.1	1.0	85.9	.....	3.0
Fruit	1,135.0	986.3	9.1	2.3	131.6	5.7
Sugar	193.0	.....	.....	.....	193.0	.....
Total food consumed	2,848.0	1,344.6	359.5	303.3	758.2	82.4
Feces	85.0	.....	37.5	11.4	23.4	12.7
Amount utilized	.....	.....	322.0	291.9	734.8	69.7
Per cent utilized	.....	.....	89.6	96.2	96.9	84.6
Experiment No. 699, subject W. E. T.:						
Biscuits containing peanut flour	839.0	205.3	206.6	127.2	256.4	43.5
Butter	69.0	7.6	0.7	58.6	.....	2.1
Fruit	1,208.0	1,049.8	9.7	2.4	140.1	6.0
Sugar	108.0	.....	.....	.....	108.0	.....
Total food consumed	2,224.0	1,262.7	217.0	188.2	504.5	51.6
Feces	45.0	.....	18.6	9.5	9.6	7.3
Amount utilized	.....	.....	198.4	178.7	494.9	44.3
Per cent utilized	.....	.....	91.4	95.0	98.1	85.9
Average food consumed per subject per day	835.9	364.3	105.5	117.1	224.1	25.0

[1] U. S. Dept. Agr. Bul. 310 (1915), p. 21. [2] U. S. Dept. Agr. Bul. 505 (1917), p. 18.

Summary of digestion experiments with flour made from raw peanuts in a simple mixed diet.

Experiment No.	Subject.	Digestibility of entire ration.				Estimated digestibility of peanut protein alone.
		Protein.	Fat.	Carbohydrates.	Ash.	
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
696	P. K.	91.0	97.0	97.3	86.4	89.4
697	J. C. M.	89.7	97.9	96.4	91.7	87.6
698	A. A. R.	89.6	96.2	96.9	84.6	87.3
699	W. E. T.	91.4	95.0	98.1	85.9	90.5
Average		90.4	96.5	97.2	87.2	88.7

As indicated by the above table the subjects ate on an average 106 grams of protein, 117 grams of fat, and 224 grams of carbohydrate daily, which supplied approximately 2,370 calories. The average coefficients of digestibility of the protein, fat, and carbohydrate supplied by the diet as a whole were 90.4 per cent for the protein, 96.5 per cent for the fat, and 97.2 per cent for the carbohydrates.

Of the average amount of protein eaten daily (106 grams), 103 grams were supplied by the peanut biscuits, 65 grams being contributed by the peanut flour. This amount of peanut protein, much larger than that likely to be found in the ordinary mixed diet, was eaten without any noticeable digestive or other disturbances.

The digestibility of the peanut protein alone, estimated for peanut flour made from raw nuts, was found to be 88.7 per cent, a value which is not significantly different from the value (84.5 per cent) found for the proteins supplied by peanut flour made from roasted nuts. Accordingly it would appear from these figures and from the figures given above for the protein, fat, and carbohydrate of the peanut-cake diet as a whole that neither roasting nor the presence of the peanut skin materially affected the thoroughness of digestion.

SUMMARY OF ALL EXPERIMENTS WITH PEANUT FLOURS.

In order to compare carefully the values for the digestibility of protein, fat, and carbohydrate supplied by simple mixed diets, which include peanut flours ground from cakes from roasted and from raw peanuts, the results which have been obtained in the two series of experiments here reported have been brought together in the table following.

Summary of digestion experiments with flour made from peanuts in a simple mixed diet.

Experiment No.	Kind of peanut flour.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.	Estimated digestibility of peanut protein alone.
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
618	Flour from roasted nuts	P. K.	93.7	97.4	99.1	93.6	93.5
619	do	J. C. M.	86.5	95.1	98.0	84.4	75.0
620	do	C. J. W.	80.2	95.2	97.3	80.7	60.7
633	do	A. A. F.	93.5	95.0	98.3	91.5	92.9
634	do	P. K.	90.9	91.0	98.3	87.2	86.9
635	do	J. C. M.	93.4	98.1	98.8	90.9	92.6
636	do	C. J. W.	91.4	96.5	98.4	90.3	87.9
	Average		89.9	95.5	98.3	88.4	84.2
696	Flour from raw nuts	P. K.	91.0	97.0	97.3	86.4	89.4
697	do	J. C. M.	89.7	97.9	96.4	91.7	87.6
698	do	A. A. R.	89.6	96.2	96.9	84.6	87.3
699	do	W. E. T.	91.4	95.0	98.1	85.9	90.5
	Average		90.4	96.5	97.2	87.2	88.7
	Average of all tests		90.1	95.9	97.9	87.9	85.8

Considering the experiments with peanut flour as a whole it would seem fair to assume that the average data obtained for the digestibility of peanut protein should be sufficient for quite general application, since a total of eleven different tests was made with six different subjects and two different types of peanut flours. Considering the ration as a whole or considering the peanut protein alone, the coefficients of digestibility obtained with the two types of peanut flour are in close agreement. The average coefficients of digestibility for the diet as a whole—90.1 per cent for protein, 95.9 per cent for fat, and 97.9 per cent for carbohydrates—indicate that the experimental diet was, for all practical purposes, as well utilized as the ordinary mixed diet, the coefficients of digestibility [1] of which have been found to be 92 per cent for protein, 95 per cent for fats, and 97 per cent for carbohydrates. These figures would seem to indicate that peanut flour is itself well assimilated and that it did not exert any unfavorable effects upon the digestibility of the other foods included in the diet.

Comparing the average values obtained for the digestibility of peanut protein alone in the individual experiments it is found that peanut protein is 85.8 per cent digested, a figure lower than that of milk, meat, or egg proteins, about equal to those of cereal proteins, and somewhat higher than that of the common legumes. From the previously published data summarized above and the results of these experiments it appears that the peanut supplies a protein which yields essential amino acids, is well tolerated by the human body, and is very well digested. In view of these facts it seems that peanut flour prepared from high-grade press cake may well assume an important rôle in the human dietary.

[1] U. S. Dept. Agr. Bul. 142 (1902), p. 26.

GENERAL CONCLUSIONS REGARDING THE VALUE OF SOY BEAN AND PEANUT FLOURS AS FOOD.

Soy beans and peanuts are classed as a "sure crop," and both yield valuable products (press cakes) whose chief use at present is said to be for stock feeding. The boll weevil has made the growing of cotton unprofitable in some sections of the South. As a result, during the last season or two, the culture of soy beans and peanuts has increased with unusual rapidity. This situation, coupled with the present great demand for oils, has caused many of the cotton-seed-oil millers to utilize their machinery for pressing soy beans and peanuts. The resulting soy-bean and peanut press cakes when ground yield a flour very rich in protein and, as compared with cereal flours and meals, fairly rich in fat.

Chemical analyses reported by previous investigators of glycinin and arachin, soy-bean and peanut proteins, show that both, by hydrolysis, yield lysine and tryptophane, two amino acids recognized as essential for growth and maintenance.

Investigators studying the biologic value of these proteins by experiments with laboratory animals have shown that soy-bean and peanut proteins when employed as the sole source of protein in an otherwise adequate diet support in a satisfactory manner the normal body processes of growth, maintenance, and reproduction.

In view of these facts it seemed highly desirable to study the digestibility of the proteins supplied by soy-bean and peanut flours prepared by grinding press cakes obtained by the expression of oil from clean sound soy beans and peanuts.

The experiments here reported were made with normal young men students engaged in moderately active pursuits. The soy-bean and peanut flours were eaten in the form of a well-known type of "quick bread" or "biscuit" as a part of a simple mixed diet. None of the subjects reported any digestive or other physiological disturbances in connection with these diets, indicating that as regards the time and method of cooking, the soy-bean and peanut flours were satisfactory.

The figures, 85 per cent for the digestibility of soy-bean protein contained in ground cake and 86 per cent for the digestibility of peanut protein present in ground cake, indicate a very satisfactory utilization of these proteins by the human body. If allowance has been made for that portion of the fecal nitrogen which resulted from epithelial cells and bacteria instead of including it in the undigested residues of the soy beans and peanuts, the coefficients of digestibility of soy-bean and peanut proteins would have been somewhat higher.

The figures obtained for the digestibility of the proteins supplied by soy-bean and peanut press-cake flours compare very favorably with those obtained for cereal proteins and are somewhat higher than

those obtained for some other legume proteins. Perhaps the difference between the digestibility of the soy-bean and peanut proteins as shown by these experiments and the digestibility of the common legumes reported by other investigators is due in part at least to the soy bean and peanut having been finely ground. It is hoped that additional experiments will give more data on this point.

No attempt was made to ascertain the limit of tolerance for soy-bean and peanut flours when included in a simple mixed diet, but since in seven experiments with soy beans the subjects ate an average of 70 grams daily of soy-bean protein and in four experiments with peanut flour the subjects ate an average of 65 grams of peanut protein daily without any observed symptoms of physiological disturbance, it should be very evident that these proteins are tolerated by the human body in amounts in excess of those which are likely to be found in the ordinary mixed diet.

Since in household economy the soy-bean and peanut flours would be used to supplement wheat or other cereal flours, and since numerous investigations of the value of soy-bean and peanut proteins for food purposes indicate that these proteins have a nutritive value nearly if not quite equivalent to that of meat, milk, and egg proteins, it would seem that these flours could be very properly classed as both wheat and meat substitutes.

From these facts it is very evident that it is highly desirable to use for human food such soy-bean and peanut press cakes, by-products of the oil mills, as can be properly prepared for food purposes rather than to continue to use them exclusively for stock feeding and fertilizing purposes.

The data obtained in this and other investigations give sufficient evidence to justify the belief that soy-bean and peanut flours, rich in proteins that are well digested and of high biologic value, should prove especially valuable additions to the human dietary.

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